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FUNGOUS DISEASES OF THE GRAPE
AND THEIR TREATMENT,

BY

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LETTER OF SUBMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF VEGETABLE PATHOLOGY,
Washington, D. C., February 16, 1891.

SIR: I have the honor to submit herewith a bulletin on the treatment of four of our most destructive grape diseases. It is now nearly two years since our last publication on this subject was issued, and during that time many new facts have been brought out. The accompanying pages have been written for the purpose of bringing together these facts in convenient form for the practical grape grower.

Respectfully,

B. T. GALLOWAY,
Chief of the Division of Vegetable Pathology.

Hon. J. M. RUSK,
Secretary.

FARMERS' BULLETINS.

The bulletins of this series may be obtained by applying to the Secretary of Agriculture, Washington, D. C. The following have been previously issued:

Farmers' Bulletin No. 1. The What and Why of Agricultural Experiment Stations. (A brief explanation of the object, origin, and development of the stations, their work in Europe and in the United States, and the operations of the Office of Experiment Stations of the Department of Agriculture.) Prepared by the Office of Experiment Stations. pp. 16. Issued June, 1889.

Farmers' Bulletin No. 2. The Work of the Agricultural Experiment Stations. (Illustrations of Station Work in the following lines: better cows for the dairy; fibrin in milk; bacteria in milk, cream, and butter; silos and silage; alfalfa; and field experiments with fertilizers.) pp. 16. Prepared by the Office of Experiment Stations. Issued June, 1889.

Farmers' Bulletin No. 3. The Culture of the Sugar Beet. (Treats of the climatic conditions, soil, fertilizers, and cultivation required by the sugar beet, cost of growing, time to harvest, and method of siloing; describes briefly the process of beet sugar manufacture, and gives statistics of sugar production and consumption.) By H. W. Wiley, chemist of the Department of Agriculture. pp. 24. Issued March, 1891.

FUNGUS DISEASES OF THE GRAPE AND THEIR TREATMENT.

GRAPE DISEASES.

There are but four fungous diseases of the grape in this country which occasion sufficient damage to warrant our attention in this bulletin. They are: (1) The grape peronospora or downy mildew; (2) powdery mildew; (3) black rot, and (4) anthracnose. These we shall endeavor to describe in such a way that anyone not familiar with them may be able to recognize them and act accordingly.

Grape peronospora or downy mildew, brown rot, and gray rot.—The fungus causing these diseases is known to botanists as *Peronospora viticola*. It attacks the leaves, young wood, flowers, and fruit. On the leaves it usually manifests itself first in the form of greenish yellow or brownish spots on the upper surface, while on the lower side corresponding parts are covered with a white frost-like growth. As the disease progresses the frost-like patches may disappear, leaving only the brown leaf, which soon dries up and falls off. Young wood and flowers are affected in much the same way, but owing to their structure the downy or frost-like stage is more pronounced. This form of the disease is known as the downy mildew, and in some sections it causes the only serious damage. On the fruit the fungus occurs in two forms, causing what is known as brown and gray rot. The former disease as a rule does not make its appearance until the berries are nearly grown. At this time a brownish purple spot will appear on one side of the berry and in a short time the whole fruit is involved, turning brown and ultimately becoming soft and wrinkled. The skin usually remains unbroken until the berry drops to the ground, which it does at the slightest touch or jar. In gray rot the fruit is covered with the same frost-like growth seen on the leaves. The berries are literally plastered together with the fungus, the effect being so peculiar and so different from any other disease that no one will fail to recognize it.

Powdery mildew.—This usually appears about midsummer, attacking the leaves, young wood, and berries. Occasionally, however, it appears earlier in the season and in such cases is often very destructive to the flowers. It forms on the various parts attacked a powdery mealy growth, this being very marked on the leaves, where it is usually more abundant upon the upper surface. The berries attacked often crack,

exposing the seed in a very peculiar manner. Upon close examination of any part of the vine affected with powdery mildew fine delicate threads which make up the vegetative portion of the fungus may be seen. This in itself is enough to distinguish the disease from downy mildew, the only malady for which it is likely to be mistaken.

Black rot.—Black rot is so widespread and well known that it is hardly necessary to describe it. It may be well, however, to call attention to the fact that the disease usually appears first on the leaves and young shoots, causing reddish brown or blackish spots. Ten or 15 days later the berries are attacked, the first evidence of this being a black or brownish spot at one or more points on the surface. Soon the whole berry turns brown, then black, and finally becomes hard and leathery, but as a rule clings firmly to its stalk.

Anthracnose.—Like the downy mildew and black rot, anthracnose attacks the leaves, growing shoots, and young berries.

Leaves, when first affected with the disease, show minute blackish brown spots, which are surrounded with a slightly raised, darker-colored margin. Ultimately the centers of the spots turn gray, and not infrequently the diseased parts crack across or separate from the surrounding healthy portions, leaving the leaf full of small, ragged holes. On the shoots the disease manifests itself in much the same way as it does on the leaves. As it progresses, however, the spots usually become darker at their center, and often run together, forming more or less elongated diseased areas which gradually eat their way into the wood. The scars made in this way may often be seen on the ripened wood, and it is now known that the mycelium or body of the fungus passes the winter in the tissues surrounding these places.

Anthracnose on the fruit, or bird's-eye rot, as it is sometimes called, first appears as a blackish or brown circular spot surrounded by a narrow, somewhat darker rim. As the spots increase in size the color undergoes various changes. In some cases the outside rim remains dark brown, while inside of this is a wider zone of a beautiful vermilion color surrounding a grayish center. Frequently the spots, when less than one-eighth of an inch in diameter, assume a grayish-white color, which they retain throughout the rest of their growth. When the berries are small the disease often manifests itself in another way. The fruit turns brown, shrivels up, and, at the same time, little pinkish pustules appear on the surface. The grape may also develop unequally, the affected side being flattened.

This form of rot is not characterized by a softening of the tissues, as in the case with others we have mentioned. The tissues slowly collapse, but at the same time become hard and wrinkled.*

Believing that the foregoing remarks will, after a little study, enable anyone to recognize these various diseases, we will next direct our attention to the remedies and their preparation.

REMEDIES AND THEIR PREPARATION.

Experience has shown that for all practical purposes there are but four fungicides worthy of consideration in this connection: (1) The simple solution of copper sulphate; (2) the Bordeaux mixture; (3) the ammoniacal solution of copper carbonate; and (4) eau celeste. Of course there are other preparations which bid fair to be fully as valuable as any of the preceding, but as yet we do not know enough about them to recommend their extended use unqualifiedly.

(1) *Simple solution of copper sulphate*.—This is prepared in the usual way by simply dissolving 1 pound of the copper sulphate in 25 gallons of water.

(2) *Bordeaux mixture*.—The only formula now generally used is that containing 6 pounds of copper sulphate and 4 pounds of lime to 22 gallons of water. For many reasons we find it advantageous to use powdered copper; still, when time is not an important element, the crystals answer just as well and, as a rule, are from 2 to 3 cents cheaper per pound. In our work we usually provide ourselves with three barrels, one of which we divide in the middle, making two tubs holding 22 gallons. One of the barrels we use for water, which is obtained at the nearest well, clear stream, or pond. Twelve pounds of copper sulphate are weighed out and placed in one of the tubs, 6 or 7 gallons of water are added and the copper stirred in this until the water is blue. This blue solution is then poured into the empty barrel and 6 or 7 gallons more of water are poured into the tub containing the copper and the latter is stirred as before. This process is repeated until all of the copper is dissolved, it being found that 16 or 20 gallons of water are necessary for this purpose, providing crystals are used and the water is cold. Powdered copper sulphate requires much less labor and water to dissolve it, and for this reason we prefer it to the crystals. All of the copper being dissolved, 8 pounds of lime are slacked in one of the tubs. After slacking, enough water is added to make a rather thin whitewash, then this is poured slowly into the barrel containing the copper solution. We usually strain the whitewash through a coarse gunny sack, having the latter stretched over the head of the barrel. The straining removes all of the small pieces of lime, sticks, straws, etc., which have a tendency to clog the nozzle. After pouring in all the whitewash, more water is added until the barrel is filled to within 5 inches of the top. The solution is then thoroughly stirred, when it is ready for use.

Of course, the above process can be variously modified as occasion may require. Instead of hauling the water to the vineyard it may be found more convenient to prepare the mixture near the water supply and then convey it where it is to be used either in barrels or tanks made for the purpose.

In one or two parts of the country, notably central Virginia, it is claimed that Bordeaux mixture of the above strength is apt to injure the foliage of some varieties, especially Norton's Virginia. The only way

we can account for this is that the soil and climate of these regions is such as to render the vines more susceptible to the action of fungicides, or else that proper care is not exercised in the use of these preparations. It is more likely, however, that the trouble is due to climatic influences, and if this is the case it becomes necessary to reduce the amount of copper somewhat. Around Charlottesville, Va., grape growers are using a formula containing from 2 to 3 pounds of copper sulphate and $1\frac{1}{2}$ to 2 pounds of lime to 22 gallons of water very successfully. We would not recommend the use of this formula excepting in the very rare cases where the vines appear to be injured by the stronger mixture. In this connection it might be well to say that injury has sometimes resulted to the vines from the use of the Bordeaux mixture made with air-slacked lime. In all cases it is best to use *fresh* lime, but when this can not be readily obtained it would be well to use 5 or 6 pounds of the air-slacked for each 6 pounds of copper.

(3) *Ammoniacal solution of copper carbonate.*—(a) In an ordinary water pail dissolve 5 ounces of copper carbonate in 3 pints of aqua ammonia, having a strength of 26°. If 3 pints of ammonia are not sufficient to completely dissolve the copper, add enough to bring about this result. When completely dissolved, pour the solution into a barrel and fill the latter with water.

Ammoniacal solution of copper carbonate.—(b) Mix thoroughly 6 ounces of pulverized ammonia carbonate and 1 ounce of copper carbonate. Keep in an air-tight vessel, and when ready for use dissolve in 10 gallons of water.

This preparation is not as expensive as the preceding; moreover it has other advantages, namely, ease of preparation, portability, etc. When only a few acres are to be treated the chemicals might be obtained ready mixed, put up in air-tight cans. A 5-pound can, sufficient for 100 gallons of the solution, put up in this way should not cost over 50 cents. Buying the chemicals in quantity and mixing them at home will reduce the expense considerably. A further reduction will result if the copper carbonate is made at home according to directions which are given further on.

(4) *Eau celeste.*—Dissolve 2 pounds of copper sulphate in 6 or 8 gallons of water. When thoroughly dissolved add 3 pints of strong ammonia and dilute to 50 gallons. Last season we prepared and sent out a mixture for trial which in some cases gave very good results, so far as its fungicidal properties were concerned. It has the same objection as eau celeste, namely, that it is not safe to use it on tender foliage. The mixture consists of equal parts of ammoniated copper sulphate and ammonia carbonate. It was put up in air-tight cans, and for use was simply dissolved in water at the rate of 1 pound to 25 gallons. The solution thus obtained is practically the same as eau celeste made in the usual way. One pound of the mixture costs 45 cents, making it more expensive than eau celeste prepared according to the old formula.

The only advantage the mixture possesses is that it enables those who may wish to use the eau celeste in small quantities to do so without going to the trouble of buying the copper sulphate, aqua ammonia, etc., and mixing them.

(5) *Eau celeste, modified formula.*—Dissolve 4 pounds of copper sulphate in 10 or 12 gallons of water. Add 3 pints of strong ammonia, dilute to 50 gallons, and add 5 pounds of common washing soda. Stir thoroughly and the solution is ready for use.

This is one of the oldest fungicides, having been used first in 1887.* It rarely injures the foliage, and for this reason is much more desirable than the simple eau celeste. The ammoniacal solution has, however, about superseded these preparations in the treatment of nearly all plant diseases.

Convenient measures.—It is often inconvenient to take scales into the field; moreover, when they are at hand it requires considerable time to weigh out the various chemicals used. If the following facts are remembered it will frequently save time and trouble:

	Quarts.
6 pounds of copper sulphate, crystals.....	2½
6 pounds of copper sulphate, powdered.....	2
4 pounds of lime, unslaked, in pieces the size of pigeons' eggs.....	2½
4 pounds of lime, slaked.....	3

A convenient measure for the copper carbonate may be made from a baking-powder can or something similar. First weigh the can, then put in 5 ounces of the chemical and mark the place. We have 1-ounce, 2-ounce and 5-ounce cans made in this way and find them exceedingly useful and labor-saving.

Manufacturing copper carbonate.—In this connection, and before proceeding with the directions for treatment, it may be well to call attention to the fact that if desirable the copper carbonate can be manufactured at home at about one-third the price usually charged for it in the wholesale markets. Following are directions for manufacturing it:

In a tub or barrel dissolve 6 pounds of copper sulphate in hot water. In another suitable vessel dissolve 7 pounds of sal soda in hot water. When the two solutions are cool, pour the second slowly into the first, then add water until the tub or half-barrel is full. Stir the solution thoroughly and let it stand for 24 hours, then siphon off the clear liquid and add fresh water. Stir again, and again allow the solution to stand 24 hours; siphon off the clear liquid as before, then remove and dry the sediment, which is carbonate of copper. Using the above quantities of copper sulphate and sal soda there will be formed 3 pounds of copper carbonate. Sal soda sells at wholesale for 1½ cents per pound, so that on this basis the necessary chemicals to make 3 pounds of copper carbonate will cost 46½ cents, or 15½ cents for 1 pound. The usual wholesale price for this chemical is 40 cents per pound.

* Circular No. 5.

TREATMENTS.

Downy mildew, brown and gray rot.—Use either the ammoniacal copper carbonate solution, eau celeste, or the Bordeaux mixture, preferably the first on account of its being cheaper and not so likely to injure the foliage. Make the first application about the time the berries are well formed, which, as a rule, is 10 or 12 days in advance of the mildew. Repeat the sprayings every 12 or 15 days, or more often if there are frequent heavy rains, until the berries begin to color. In some sections where the mildew is unusually severe it may prove advantageous to make one or two sprayings after the fruit is harvested in order to insure perfect ripening of the wood.

Eau celeste is now largely used in the treatment of this disease in northern Ohio, especially on the islands of Lake Erie. In this climate it does not seem to injure the foliage at all, but this can not be said of any other section so far as we know.

Powdery mildew.—The fungus causing this disease succumbs readily to treatment with any of the copper compounds.* Where the disease exists alone we would recommend the use of the ammoniacal copper carbonate solution. In regions where the mildew is common the vines should be carefully watched, and at the first sign of the trouble, applications should begin and be repeated at intervals of 12 or 15 days. Excepting on the Pacific coast, there are comparatively few regions where this disease exists alone, and of course where it is associated with any of the other maladies mentioned in this paper one treatment will answer for all.

Black rot.—Four general methods of treating this disease are now practiced by us, as follows:

(1) In spring, after the vines have been pruned and before the buds begin to swell, spray the wood with the simple solution of copper sulphate. About the time the leaves are one third grown apply the Bordeaux mixture. Repeat the latter treatment when the vines are in full bloom and thereafter at intervals of 10 or 12 days until the fruit begins to ripen.

(2) Omit the spraying with the simple solution, but for the rest follow the rules laid down in No. 1.

(3) Treat exactly the same as No. 2, except use the ammoniacal solution instead of the Bordeaux mixture.

(4) For the two first treatments apply the Bordeaux mixture the same as in No. 2, then for the rest of the season use only the ammoniacal copper carbonate solution.

In regard to these various methods it may be said that No. 1 is objectionable on account of the additional cost of the treatment with the simple solution. In the majority of cases it is doubtful if these early applications do any real good; still, in an old vineyard which has never

*This does not refer to Vinifera stock.

been treated, it may prove beneficial by destroying many of the dormant spores. Method 2 is probably the most reliable of all, as it has stood the test of several seasons and has never failed us, no matter how favorable the weather is for black rot and other diseases. It is more expensive than either No. 3 or No. 4, moreover the mixture by spotting the fruit may render it unfit for market. The plan outlined under No. 3 last season gave fully as good results as any of the others. It possesses the advantage of being cheap and requires no special apparatus to carry it out. The last method, or No. 4, has no particular advantages over the others unless it be that it allows the use of the Bordeaux mixture at a critical period without danger of spotting the fruit. All things considered we should advocate for an ordinary season either No. 3 or No. 4, but if heavy rains are frequent we would recommend that the Bordeaux mixture alone be used.

Anthracnose.—This disease rarely occurs alone. As a rule it is found associated either with black rot or mildew, and when this is the case no additional treatment can, in the present condition of our knowledge, be recommended. For anthracnose alone the only remedy that has given any beneficial results is the Bordeaux mixture, applied in the same manner as recommended for black rot.

General treatment.—In many parts of the country it is a common thing to find downy mildew, black rot, and anthracnose all working together. In such cases the question has arisen as to whether we could not devise some general treatment which would hold all of those maladies in check. Experience has shown that any of the treatments recommended for black rot will do this providing the anthracnose is not unusually severe.

METHODS OF APPLYING THE REMEDIES.

It is of the utmost importance that the remedies reach all the green parts of the vine. These do not need to be drenched; on the contrary they only require a thin film of the fungicide to protect them against infection. It is only possible to obtain this even distribution by means of careful work and the use of suitable spraying pumps and nozzles. It is next to useless to resort to watering cans and old brooms as many do, although this treatment is perhaps better than none at all. At the present time every gardener, farmer, and fruit grower should own a spraying machine of some kind. There are so many in the market and they can be obtained so readily that it is useless to mention any particular styles. Where one has only a few vines one of the ordinary brass syringes sold by florists for \$1.50 will answer. For medium-sized vineyards, *i. e.*, 10 to 20 acres, the knapsack* form of pump provided with spraying nozzles is a most excellent machine. These pumps are now largely used in vineyards where the ground is uneven or where it is

*For full description with working drawings of a knapsack pump and spraying nozzles see Journal of Mycology, Vol. 6, No. 11.

difficult to get in with the large horse-power machines. The prices of these pumps complete range from \$14 to \$25; they are sold now by nearly all reputable agricultural implement dealers. For large vineyards where the ground is level large machines may be used. Machines of this kind are made which will spray an acre in 30 minutes, requiring the labor of two men, two horses and a boy to manage them.

A very convenient machine suitable for large vineyards can be rigged up at home, the materials necessary being a barrel, a strong force pump having two discharge pipes, two pieces of three-quarter-inch hose each 16 feet long, and two spraying nozzles. This outfit complete need not cost over \$15. The apparatus is placed in a wagon or cart, which is drawn by a horse. A boy manages the horse while one man remains in the wagon or cart and works the pump; two more men follow behind using the nozzles and spraying two rows at a time. When such a machine as this is used it will keep two men busy preparing the fungicide.

COST OF THE TREATMENTS.

The cost of the treatments will depend in a large measure upon the kind of spraying apparatus used and prices paid for chemicals. With a good spraying machine and chemicals obtained at wholesale figures it is safe to estimate the total cost of treating, say an acre of bearing grapes with the principal remedies six times, as follows:

	Cents.
Bordeaux mixtureper vine..	3
Ammoniacal solutiondo....	2
Bordeaux mixture, two sprayings; ammoniacal solution, four sprayings..do....	2½
Additional expense of spraying with simple solution of copper sulphate..do....	½

These figures are based upon the fact that the chemicals are purchased at the following usual wholesale prices:

	Cents.
Copper sulphate, crystalsper pound..	6
Copper carbonatedo....	40
Aqua ammonia, 26°.....do....	8
Ammonia carbonatedo....	11
Limeper bushel..	30

It requires on an average 3 quarts of liquid per vine for the season's work of six applications. Taking the foregoing as a basis, we will, to be more explicit, estimate the cost of treating an acre of bearing vines, assuming that the rows are 10 feet apart and the vines are 8 feet apart in the row. This will give us 544 vines to the acre. Multiplying 544 by ¾ will give us 408, the number of gallons required to treat an acre. Four hundred and eight gallons of the Bordeaux mixture will cost as follows:

Copper sulphate, 111 pounds, at 6 cents.....	\$6.66
Lime, 74 pounds50
Total.....	\$7.16

With an ordinary knapsack sprayer it will require about 92 hours of labor to make six applications in the proper manner. Estimating this labor at 10 cents an hour we have \$9.20. Adding this to the cost of chemicals brings the total up to \$16.36. This amount divided by 544, the number of vines to the acre, gives practically 3 cents. These figures, we believe, will enable any one to answer such questions as may arise in connection with this part of the subject, taking it for granted that the labor for each liquid is the same.

CONCLUDING REMARKS.

Under this heading we wish to call special attention to the importance of early treatment, and the absolute necessity of always bearing in mind that the work is wholly preventive. The man who waits until the mildew or black rot has a fair start in his vineyard, before beginning the fight, might probably just as well pour his fungicides on the ground for all the good it will do his vines.

There is no longer any question as to the efficacy of these treatments, as is evidenced by the fact that thousands of grape-growers are now adopting them, and are saving in consequence all the way from 50 to 90 per cent of their crop. As the matter now stands, success rests wholly with the one who plans and carries on the work.

One other matter in this connection seems worthy of attention, and that is this: It should be the aim of every fruit grower to keep his plants in health whether they are bearing fruit or not. If they do not bear fruit this year they will in all probability do so the next. For this purpose it is necessary that they shall have stored up sufficient material to properly mature the fruit, and this is made possible only by the presence of vigorous, healthy foliage. Spray, therefore, if it will save the foliage, for there is no doubt that the little expended in this way will, in the end, yield a handsome profit.

PUBLICATIONS OF THE DIVISION OF VEGETABLE PATHOLOGY.

Frequent requests are received for bulletins of this Division which are out of print. The following list includes all the publications issued to date. Those still on hand for distribution are indicated by an asterisk (*). It will be seen that in this series Numbers 1, 3, 4, and 6 are missing. These represent bulletins of the Botanical Division.

1. Bulletin No. 2. Fungous Diseases of the Grape. 1886, pp. 136, pl. 7.
2. Bulletin No. 5. Report on the experiments made in 1887 in the Treatment of Downy Mildew and Black Rot of the Grape. 1888, pp. 113.
3. Bulletin No. 7. Black Rot. 1888, pp. 29, pl. 1.
4. Bulletin No. 8. A record of Some of the Work of the Division. 1889, pp. 69.
5. Bulletin No. 9. Peach Yellows. 1889, pp. 254, pl. 36.
6. Bulletin No. 10. Report on the Experiments made in 1888 in the Treatment of Downy Mildew and Black Rot of the Grape, pp. 61.

7. Bulletin No. 11.* Report on the Experiments made in 1889 in the Treatment of Fungous Diseases of Plants. 1890, pp. 119.
8. Journal of Mycology, Vol. 5, Nos. 1, 2, 3 and 4, 1889, pp. 249, pl. 14.
9. Journal of Mycology, Vol. 6, Nos. 1, 2,* and 3,* 1890, pp. 135, pl. 6.
10. Circular No. 1. Treatment of Downy Mildew and Black Rot of the Grape. 1885, pp. 3.
11. Circular No. 2. Grape Vine Mildew and Black Rot. 1885, pp. 3.
12. Circular No. 3. Treatment of Grape Rot and Mildew. 1886, pp. 2.
13. Circular No. 4. Treatment of the Potato for Blight and Rot. 1886, pp. 3.
14. Circular No. 5. Fungicides or Remedies for Plant Diseases. 1888, pp. 10.
15. Circular No. 6.* Treatment of Black Rot of the Grape. 1888, pp. 3.
16. Circular No. 7.* Grape Vine Diseases. 1889, pp. 4.
17. Circular No. 8.* Experiments in the Treatment of Pear Leaf Blight and Apple Powdery Mildew, pp. 11.
18. Circular No. 9. Root Rot of Cotton. 1889, pp. 4.

